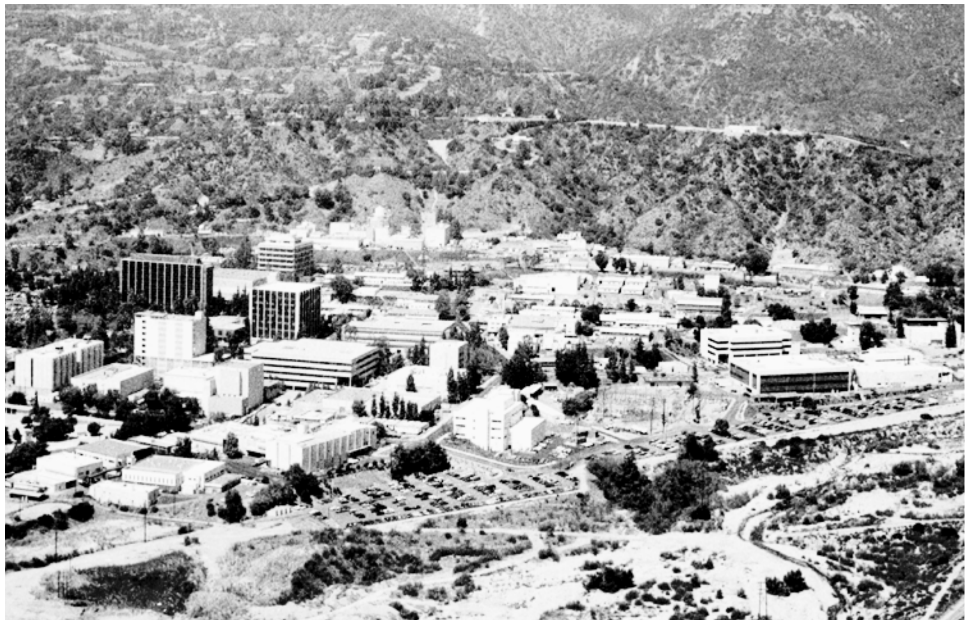
Jet Propulsion Laboratory



A new generation of space missions to explore the solar system and the universe beyond is unfolding at the Jet Propulsion Laboratory.

The American space age began January 31, 1958, with the launch of the first U.S. satellite, Explorer 1, built and controlled by JPL. In the nearly four decades since then, JPL has led the world in exploring all of the solar system's known planets, except Pluto, with robotic spacecraft. The tools developed at JPL for its spacecraft expeditions to other planets have also proved invaluable in providing new insights and discoveries in studies of Earth, its atmosphere, climate, oceans, geology and the biosphere.

Approaching the new millennium as the 21st century begins, JPL continues as a world leader in science and technology, breaking new ground in the miniaturization and efficiency of spacecraft components. At the same time, the Laboratory is pushing the sensitivity of space sensors and broadening their applications for a myriad of scientific, medical, industrial and commercial uses on Earth.

JPL is a federally funded research and development facility managed by the California Institute of Technology for the National Aeronautics and Space Administration.

JPL's Beginnings

JPL's history dates to the 1930s, when Caltech professor Theodore von Karman conducted pioneering work in rocket propulsion. Von Karman, head of Caltech's Guggenheim Aeronautical Laboratory, gathered with several graduate students to test a primitive rocket engine in a dry riverbed wilderness area in the Arroyo Seco, a dry canyon wash north of the Rose Bowl in Pasadena, California. Their first rocket firing took place there on October 31, 1936.

After the Caltech group's successful rocket experiments, von Karman, who also served as a scientific adviser to the U.S. Army Air Corps, persuaded the Army to fund development of strap-on rockets (called JATO, for "jet-assisted take-off") to help overloaded Army airplanes to take off from short runways. The Army helped Caltech acquire land in the Arroyo Seco for test pits and temporary workshops. Airplane tests at nearby air bases proved the concept and tested the designs. by this time, World War II had begun and the rockets were in demand. The scientists started a rocket manufacturing company, called Aerojet.

As the researchers wound up the JATO work, the Army Air Corps asked von Karman for a technical analysis of the German V-2 program just discovered by Allied intelligence. He and his research team then proposed a U.S. research project to understand, duplicate and reach beyond the guided missiles beginning to bombard England. In the proposal, the Caltech team referred to their organization for the first time as "the Jet Propulsion Laboratory."

Funded by Army Ordnance, the Jet Propulsion Laboratory's early efforts would eventually involve technologies beyond those of aerodynamics and propellant chemistry, technologies that would evolve into tools for space flight, secure communications, spacecraft navigation and control and planetary exploration.

The team of about 100 rocket engineers began to expand, and the team began testing in the California desert of small unguided missiles (named Private) that reached a range of nearly 18 kilometers (about 11 miles). They experimented with radio telemetry from missiles, and began planning for ground radar and radio sets. By 1945, with a staff approaching 300, the group had begun to launch test vehicles from White Sands, New Mexico, to an altitude of 60 kilometers (200,000 feet), monitoring performance by radio.

Control of the guided missile was the next step, requiring two-way radio as well as radar and a primitive computer (using radio tubes) at the ground station. The result was JPL's answer to the German V-2 missile, named Corporal, first launched in May 1947, about two years after the end of war with Germany.

Developing a missile that would fly and survive in the field involved testing the aerodynamic design and the durability under vibration and other stresses. The team developed a supersonic wind tunnel and an array of environmental test technologies, all of which had wider use and came to support outside customers. Developing so complex a device as a missile to fly unaided and beyond reach of repair meant a new degree of quality, new test techniques, and a new discipline called system engineering.

Subsequent Army work further sharpened the technologies of communications and control, of design and test and performance analysis. This made it possible for JPL to develop the flight and ground systems and finally to fly the first successful U.S. space mission, Explorer 1. The entire three-month effort began in November 1957 and culminated with the successful launch on January 31, 1958.

On December 3, 1958, two months after NASA was created by Congress, JPL was transferred from Army jurisdiction to that of the new civilian space agency. It brought to the new agency experience in building and flying spacecraft, an extensive background in solid and liquid rocket propulsion systems, guidance, control, systems integration, broad testing capability and expertise in telecommunications using low-power spacecraft transmitters and very sensitive Earth-based antennas and receivers.

The Laboratory now covers some 72 hectares (177 acres) adjacent to the site of von Karman's early rocket experiments and employs about 6,500 people (about 5,500 are Caltech employees and about 1,000 are contractors). Jet propulsion is no longer the focus of JPL's work, but the world-renowned name remains the same.

Planetary Exploration

In the 1960s, JPL began to conceive and execute robotic spacecraft to explore other worlds. This effort began with the Ranger and Surveyor missions to the Moon, paving the way for NASA's Apollo astronaut lunar landings. During that same period and through the early 1970s, JPL carried out Mariner missions to Mercury, Venus and Mars.

Mariner 2 became the first spacecraft to fly by another planet when it was launched August 27, 1962, to Venus (Mariner 1 was lost because of a launch vehicle error). Other successful Mariners included Mariner 4, launched in 1964 to Mars; Mariner 5, launched in 1967 to Venus; Mariner 6, launched in 1969 to Mars; Mariner 7, launched in 1969 to Mars; and Mariner 9, launched in 1971 to orbit Mars.

Mariner 10 became the first spacecraft to use a "gravity-assist" boost from one planet to send it on to another — a key innovation in spaceflight that would later enable the exploration of the outer planets that would have otherwise been impossible. Mariner 10's launch in November 1973 delivered the spacecraft to Venus in February 1974, where a gravity-assist swing-by allowed it to fly by Mercury in March and September that year.

The first search for life on Mars, part of NASA's Viking mission, was launched in 1975 and involved two orbiter spacecraft and two Mars landers. The elaborate mission was divided between several NASA centers and private U.S. aerospace firms, with JPL building the Viking orbiters, conducting mission communications and eventually assuming responsibility for management of the mission.

Credit for the single mission that has visited the most planets goes to JPL's Voyager Project. Launched in 1977, the twin Voyager 1 and Voyager 2 spacecraft flew by the planets Jupiter (1979) and Saturn (1980-81). Voyager 2 then went on to an encounter with the planet Uranus in 1986 and a flyby of Neptune in 1989. Early in 1990, Voyager 1 turned its camera around to capture a series of images assembled into a "family portrait" of the solar system. Still communicating their findings as they speed out toward interstellar space, the Voyagers are expected to communicate information about the Sun's energy field until perhaps the second decade of the 21st century.

In 1989 and 1990 NASA's Space Shuttle helped launch three JPL-managed missions to other planets:

Magellan used a sophisticated imaging radar to piece the cloud cover enshrouding Venus and map the planet's surface. Magellan was carried into Earth orbit in May 1989 by Space Shuttle Atlantis. Released from the Shuttle's cargo bay, Magellan was propelled by a booster engine toward Venus, where it arrived in August 1990. It completed its third 243-day period mapping the planet in September 1992. Magellan mapped variations in Venus's gravity field before the mission ended in October 1994. At the conclusion of the mission, flight controllers commanded Magellan to dip into the atmosphere of Venus in a test of aerobraking -- a technique for using atmospheric drag to slow spacecraft that will be used in future planetary missions.

After six-year journey, the Galileo spacecraft and its atmospheric probe arrived at Jupiter on December 7, 1995. The descent probe successfully completed its nearly one-hour mission into Jupiter's atmosphere the same day that the Galileo spacecraft entered orbit for its two-year mission around the giant planet. The mission began October 18, 1989, with a launch from on Space Shuttle Atlantis and an Inertial Upper Stage booster. Relying on gravity-assist swingbys to reach Jupiter, Galileo flew past Venus once and Earth twice. Along the way Galileo flew by the asteroid Gaspra in October 1991 and the asteroid Ida on August 28, 1993. On its final approach to the giant planet, Galileo observed Jupiter being bombarded by fragments of the broken-up comet Shoemaker-Levy 9. On July 12, 1995, Galileo separated from its atmospheric probe and the two spacecraft flew in formation to their final destination. On December 7, 1995, Galileo fired its main engine to enter Jupiter orbit and collected data radioed from the probe during its parachute descent into the planet's atmosphere. On June 27, 1996, the spacecraft performed its first targeted flyby of a jovian moon when it passed close to Ganymede, Jupiter's largest natural satellite.

NASA's shuttle fleet again launched a probe bound for other parts of the solar system when the Space Shuttle Discovery carried aloft Ulysses in October 1990. A joint mission between NASA and the European Space Agency, this project for the first time sent a spacecraft out of the ecliptic — the plane in which Earth and other planets orbit the Sun — to study the Sun's north and south poles. Ulysses first flew by Jupiter in February 1992, where the giant planet's gravity flung it into an unusual solar orbit nearly perpendicular to the ecliptic plane. The prime mission concluded in September 1995, followed by an extended mission which continues to return new information about the Sun.

The mission of Mars Observer, launched aboard a Titan III rocket September 25, 1992, ended with disappointment in August 1993 when contact was lost with the spacecraft shortly before it was to enter orbit around Mars. Putting Mars Observer's spare instruments to use, however, JPL and its industrial partner Lockheed Martin are quickly completing a spacecraft to accomplish a majority of the original mission's science objectives.

The next JPL planetary launches will be those of Mars Global Surveyor and Mars Pathfinder, scheduled in November and December 1996, respectively. Mars Global Surveyor will make highly detailed maps of the red planet from a polar orbit, while Mars Pathfinder will land on the surface carrying a small rover robot. Exploration of Earth's planetary neighbor under the Mars Surveyor program will continue in 1998 with the launch of two lightweight spacecraft, an orbiter and a lander. Later missions are planned every launch opportunity, which for Mars occurs about once every two years.

JPL is designing and building the Cassini mission to Saturn, scheduled for launch in 1997. Cassini will feature a probe, Huygens, provided by the European Space Agency, which will descend to the surface of Titan, Saturn's largest moon. Titan appears to boast organic chemistry possibly like that which led to the existence of life on Earth.

In late 1995, NASA selected a proposal by a team affiliated with JPL to develop and fly a mission called Stardust under the space agency's Discovery program of low-cost missions. Stardust will be launched in 1999 to fly within about 100 kilometers (60 miles) of the comet Wild-2 in the year 2004 and collect dust and volatile materials. Those materials will be returned to Earth in a return capsule that will parachute to a landing on a dry lake bed in Utah in 2006.

Another major initiative for a new breed of NASA spacecraft is New Millennium, a technology validation program designed to fly low-cost spacecraft with highly focused science objectives on a frequent basis in the early 21st century. Microspacecraft carrying miniaturized instruments will return a continuous flow of information to Earth.

The program embraces NASA's plan to launch at least one microspacecraft a month and to have several nearly autonomous spacecraft operating throughout the solar system simultaneously. Three validation flights will be launched by the year 2000 to prove the concepts of New Millennium technologies and, at the same time, provide opportunities for scientific exploration. The project is also exploring new ways of forming partnerships with industry and academic institutions.

Among mission concepts under study at the Laboratory, Pluto Express would send a small spacecraft past distant Pluto and its moon, Charon. In order to minimize cost while minimizing risks, the mission is being conceived as a pair of very small spacecraft using lightweight advanced-technology hardware components and advanced software technology. The Pluto mission plan calls for launch of the two spacecraft early in the next decade toward encounters with Pluto and Charon around 2010 or later.

Mission to Planet Earth

In the late 1970s, JPL engineers and scientists realized that the sensors they were developing for interplanetary missions could be turned upon Earth itself to better understand our home planet. This has led to a series of highly successful Earth-orbiting missions that have evolved into a major segment of the Laboratory's activities, now sponsored by NASA's Office of Mission to Planet Earth.

In 1978, JPL built an experimental satellite called Seasat to test a variety of oceanographic sensors including imaging radar, altimeters, radiometers and scatterometers. Many of the later Earth-orbiting instruments developed at JPL owe their legacy to the Seasat mission.

The imaging radar flown on Seasat led to a pair of missions flown on the Space Shuttle, 1981's Shuttle Imaging Radar-A (SIR-A) and 1984's Shuttle Imaging Radar-B (SIR-B). These were followed by Spaceborne Imaging Radar-C (SIR-C), an experiment teamed with the German/Italian X-Band Synthetic Aperture Radar and flown on the Space Shuttle twice in 1994. SIR-C/X-SAR's goal was to study a variety of scientific disciplines -- geology, hydrology, ecology and oceanography -- by comparing the radar images to data collected by teams of people on the ground.

Seasat also tested an altimeter that measured sea level heights from space. This concept led to a full-scale satellite mission developed jointly by JPL and the French space agency, TOPEX/Poseidon. The oceanographic satellite, launched August 10, 1992, on an Ariane 4 rocket from Kourou, French Guiana, has provided scientists with unprecedented insight into global climate and ocean interactions, currents, eddies, and new details about the global ocean seafloor. U.S. and French teams are currently working on a follow-on satellite that could be launched in the late 1990s.

Another mission with heritage in Seasat is the JPL-built NASA Scatterometer (NSCAT), an instrument that measures near-surface ocean winds from space. NSCAT is scheduled for launch in August 1996 on the Advanced Earth Observing Satellite (ADEOS) being prepared by Japan's National Space Development Agency (NASDA). JPL is also working on a follow-on instrument, called Seawinds.

JPL also designed and built an instrument called the Microwave Limb Sounder that studies the chemistry of Earth's upper atmosphere, relaying important data on topics such as ozone depletion. Early versions flew as payloads on the Space Shuttle, followed by an instrument onboard NASA's Upper Atmosphere Research Satellite (UARS) launched in September 1991. Currently, a new-generation version of the instrument is being developed to fly on a satellite for launch in 2002 under NASA's Earth Observing System (EOS) program.

JPL is also preparing several other instruments for launch under the EOS program. They include the Multi-Angle Imaging Spectro Radiometer (MISR), scheduled for launch in 1998, which will study the role of clouds in global climate; the Atmospheric Infrared Sounder (AIRS), due for launch in 2000, which will relay data on temperature and humidity in the atmosphere helping to understand how heat is exchanged between land, air, sea and the atmosphere; and the Tropospheric Emission Spectrometer (TES), planned for launch in 2002, which will help scientists understand the causes of acid rain and track trends in atmospheric chemistry on a global scale.

Astrophysics

In addition to studying Earth itself and other bodies within the solar system, JPL has produced missions that have peered deeper into the universe.

In 1996, NASA assigned JPL programmatic responsibility for the space agency’s Origins program. The program ties together a variety of proposed instruments and spacecraft missions that will conduct studies in astrophysics and search for Earth-like planets around nearby stars.

JPL designed and built the Wide Field/Planetary Camera (WFPC), the main observing instrument on NASA’s Hubble Space Telescope. After a flaw was discovered in the space telescope’s main mirror, JPL created a second-generation camera, WFPC-2, that compensated for the optical problem -- essentially like fitting Hubble with a set of corrective eyeglasses. WFPC-2 was installed by spacewalking astronauts during a shuttle mission in December 1993, allowing Hubble to fulfill its promise in producing unprecedented views of the cosmos.

JPL was also U.S. manager of the Infrared Astronomical Satellite (IRAS), a joint project of with The Netherlands and the United Kingdom. Launched in 1983, IRAS was an Earth-orbiting telescope which mapped the sky in infrared wavelengths invisible to the eye. IRAS data have led to a wealth of discoveries about the formation of galaxies, stars and planets, including the first-ever direct evidence of an emerging planetary system around a star besides the Sun -- material orbiting Vega, 26 light-years away. Previously unseen phenomena found by IRAS has led to gains in other areas of astronomy and astrophysics ranging from studies of comets to cosmology.

JPL is also planning the Space Infrared Telescope Facility (SIRTF), an innovative orbiting infrared telescope that will build upon the success of IRAS, taking a deeper and more detailed look into the infrared sky to help answer major questions about the universe. Current plans call for SIRTF to be proposed for formal approval in 1997 with launch in 2001.

Starburst galaxies -- vast clouds of molecular gas cradling the sites of newborn stars -- will be the target of the Wide-field Infrared Explorer (WIRE), a small, cryogenically cooled infrared telescope. WIRE will be launched into Earth orbit in October 1998 on a Pegasus XL vehicle as part of NASA's Small Explorer program.

Telecommunications

To provide tracking and communications for planetary spacecraft, JPL designed, built and operates NASA's Deep Space Network (DSN) of antenna stations. DSN communications complexes are located in California's Mojave Desert, in Spain and in Australia. In addition to NASA missions, the DSN regularly performs tracking for international missions sending spacecraft to deep space. DSN stations also conduct experiments using radar to image planets and asteroids, as well as experiments using the technique of very long baseline interferometry (VLBI) to study extremely distant celestial objects.

The DSN will play a major role in Space Very Long Baseline Interferometry (Space VLBI), a radio astronomy project that would combine orbiting spacecraft with ground antennas to examine extremely distant objects. As envisioned in current studies, this international project would team spacecraft built by the Russia and Japan with JPL's DSN antenna stations.

Technologies

In the three decades it has led the nation’s planetary exploration program, JPL has honed several skills and areas of innovation, including deep space navigation and communication, digital image processing, imaging systems, intelligent automated systems, instrument technology, microelectronics and more. Many of these disciplines found applications outside the planetary spacecraft field, from solar energy to medical imagery.

In the mid-1970s, in response to a world energy crisis, JPL worked to develop and apply alternate sources of electricity such as solar energy, for the Department of Energy, and electric vehicles and other alternative transport systems, for the Department of

Transportation.

The Laboratory has also applied space-based operational, communication, and information processing techniques to the needs of the Department of Defense, Federal Aviation Administration and other federal agencies. Its active technology-transfer program with the industrial community dates back to the early days of the missile program. JPL's Technology and Applications Programs Directorate oversees projects for sponsors other than NASA. Recent non-NASA projects at JPL have included Firefly, an aircraft-borne infrared fire mapping system for the U.S. Forest Service; a document monitoring system to help the National Archives safeguard the U.S. Constitution, Declaration of Independence and Bill of Rights; medical projects such as robot-assisted microsurgery and medical imaging systems, and Internet-based telemedical systems; and varied projects in such fields as advanced spacecraft and sensor technology, microelectronics, supercomputing and environmental protection.

JPL work for the Department of Defense has included the Miniature Seeker Technology Integration (MSTI), a satellite built and launched in November 1992 to demonstrate miniature sensor technology and a rapid development system. JPL also managed the U.S. Army's All Source Analysis System (ASAS) project, a battlefield information management system.

Research and development activities at JPL include an active program of automation and robotics supporting planetary rover missions and NASA's Space Station program. In supercomputing JPL has pioneered work with new types of massively parallel computers to support processing of enormous quantities of data to be returned by space missions in years to come.

In addition to the Laboratory's main Pasadena site and the three DSN complexes around the world, JPL installations include an astronomical observatory at Table Mountain, California, and a launch operations site at Cape Canaveral, Florida.

Dr. Edward C. Stone, project scientist for the Voyager mission, became director of JPL on January 1, 1991. Stone, a physicist, earned his doctorate from the University of Chicago. In addition to his JPL post he serves as a vice president of Caltech. Stone succeeded Dr. Lew Allen Jr., who was JPL director from 1982 to 1990. Dr. Bruce Murray headed the Laboratory from 1976 to 1982. Murray followed Dr. William H. Pickering, JPL's first director, who headed the Laboratory for 22 years beginning in 1954.

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JPL Spacecraft Missions

Spacecraft, Launch Date, Mission Description, Comment

Explorer 1, 1/31/58, first U.S. satellite, operated to 5/23/58

Explorer 2, 3/5/58, satellite, launch failed

Explorer 3, 3/26/58, satellite, operated to 6/16/58

Explorer 4, 7/26/58, satellite, operated to 10/6/58

Explorer 5, 8/24/58, satellite, launch failed

Pioneer 3, 12/6/58, escape attempt, in orbit to 12/7/58

Pioneer 4, 3/3/59, escaped to solar orbit, tracked to 650,000 km (400,000 mi)

Ranger 1, 8/23/61, lunar prototype, launch failure

Ranger 2, 11/18/61, lunar prototype, launch failure

Ranger 3, 1/26/62, lunar probe, spacecraft failed, missed Moon

Ranger 4, 4/23/62, lunar probe, spacecraft failed, impact

Ranger 5, 10/18/62, lunar probe, spacecraft failed, missed

Ranger 6, 1/30/64, lunar probe, impact, cameras failed

Ranger 7, 7/28/64, lunar probe, successful, 4,308 pictures

Ranger 8, 2/17/65, lunar probe, successful, 7,317 pictures

Ranger 9, 3/21/65, lunar probe, successful, 5,814 pictures

Surveyor 1, 5/30/66, lunar lander, operated 6/2/66-1/7/67

Surveyor 2, 9/20/66, lunar lander, crashed 9/23

Surveyor 3, 4/17/67, lunar lander, operated 4/20-5/4/67

Surveyor 4, 7/14/67, lunar lander, crashed 7/17

Surveyor 5, 9/8/67, lunar lander, operated 9/11-12/17/67

Surveyor 6, 11/7/67, lunar lander, operated 11/10-12/14/67

Surveyor 7, 1/7/68, lunar lander, operated 1/10-2/21/68

Mariner 1, 7/22/62, Venus probe, launch failed

Mariner 2, 8/27/62, Venus flyby 12/14/62, signal lost 1/3/63

Mariner 3, 11/5/64, Mars probe, shroud failed

Mariner 4, 11/28/64, Mars flyby 7/14/65 with pictures, signal lost 12/20/67

Mariner 5, 6/14/67, Venus flyby 10/19/67

Mariner 6, 2/24/69, Mars flyby 7/31/69 with pictures, lasted to 12/70

Mariner 7, 3/27/69, Mars flyby 8/5/69 with pictures, lasted to 12/70

Mariner 8, 5/8/71, failed Mars launch

Mariner 9, 5/30/71, Mars orbiter 11/13/71 to 10/27/72

Mariner 10, 11/3/73, Venus swingby 2/5/74, Mercury 3/29, 9/21, 3/16/75

Viking 1, 8/20/75, Mars orbiter/lander, orbit 6/19/76, land 7/20

Viking 2, 9/9/75, Mars orbiter/lander, orbit 8/7/76, land 9/3

Voyager 1, 9/5/77, Jupiter 3/5/79, Saturn 11/12/80 with pictures, continues on interstellar mission

Voyager 2, 8/20/77, Jupiter 7/9/79, Saturn 8/25/81, Uranus 1/24/86, Neptune 8/25/89, continues on interstellar mission

Seasat, 6/27/78, ocean radar satellite, operated three months

Solar Mesosphere Explorer, 10/6/81, successful

Infrared Astronomical Satellite, 1/25/83, NASA/United Kingdom/Netherlands orbiting infrared telescope, operated to 11/23/83

Magellan, 5/4/89, orbit 8/10/90 - 10/13/94, Venus radar mapper, mapped 99%

Galileo, 10/18/89, Jupiter orbiter/probe; Venus swingby 2/10/90, Earth swingby 12/8/90, asteroid Gaspra flyby 10/29/91, second Earth swingby 12/8/92, Ida flyby 8/28/93, Shoemaker-Levy observations 7/94, arrived at Jupiter 12/7/95 for two year mission and accomplished atmospheric probe portion of mission; currently conducting orbital tour

Ulysses, 10/6/90, European Space Agency/NASA solar polar mission; Jupiter swingby 2/8/92, solar southern polar passage 6/94-11/94, northern passage mid-1995

Mars Observer, 10/25/92, lost at Mars orbit insertion (8/24/93)

TOPEX/Poseidon, 8/10/92, NASA/French ocean satellite, operating

7-96 FOD